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How Optimization Supports Army Base Closure and Realignment

by

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How Optimization Supports Army Base Closure and Realignment

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In the 1990s, the Army closed 112 of its bases in the United States and realigned another 27, saving an estimated $3.1 billion. The next round of military Base Realignment and Closure (BRAC) will occur in 2005. Optimal Stationing of Army Forces (OSAF) is an optimization-based decision-support model adopted by the Army to support its 2005 BRAC.

1. ARMY STATIONING, OPTIMIZATION AND BRAC

The Army frequently plans adjustments to the stationing of its force structure as weapon systems, missions, and operations change over time, much as a large corporation plans changes to its plant infrastructure as product demand and technology change over time. Optimization models have long played a key role in developing these corporate plans (for example, see Brown et al [2001] and their references). On any given day, the Army has up to 100 units moving to meet new stationing requirements and our decision-support model, Optimal Stationing of Army Forces (OSAF), has recently helped guide some of these decisions in the United States. For example, OSAF suggested potential locations for rotary-wing training, and also helped determine a new home for the United States Army Southern Command.

The Army is legislatively more encumbered in its infrastructure decisions than corporate counterparts. A complex, politically insulated process for closing and realigning military installations in the United States is provided by Title XXIX of Public Law 101-510 (the National Defense Authorization Act for Fiscal Year 1991) as amended. This act established an independent Defense Base Closure and Realignment Commission and set in motion a process known as BRAC for 1991, 1993, and 1995, to be applied to installations in the United States. The law authorizing these three rounds has been remarkably successful in allowing the Department of Defense (DOD) to eliminate excess infrastructure [Government Accounting Office 2001]. Since 1995, the DOD has urged Congress to authorize additional BRAC rounds and in 2002 received authorization for a round in 2005.

The Army will use OSAF to support its 2005 BRAC round.

OSAF prescribes an optimal Army stationing plan for a given force structure, set of installations, available implementation dollars, and stationing restrictions such as: "the National Training Center is fixed at Fort Irwin," "the Old Guard is fixed at Fort Myer," and "ensure Apache helicopter training is restricted to Forts Bliss, Carson, and/or Hood." Each stationing plan must satisfy many unit requirements (for example, availability of buildings and ranges necessary to train a unit) and is evaluated with a set of quantitative and qualitative metrics. Reviews by Army leadership and over 60 presentations to Army general officers and their civilian counterparts over the last two years have helped us decide which stationing restrictions, unit requirements, and quantitative metrics to include, which to ignore, and which comparisons are better left for posterior expert judgment; in making these decisions, we must frequently balance tradeoffs between detail and tractability.

The Army has long used integer linear programming (see definition below) to help make stationing decisions, with the Naval Postgraduate School (NPS) and Center for Army Analysis playing a significant role in its use. Dell et al [1994] and Loerch et al [1996] describe some early work. The NPS theses by Gezer [2001] and Bayram [2002] describe integer linear programs to help the Army with stationing and infrastructure consolidation. Tarantino [2002] reports on a recent OSAF application. Dell [1998] and recent NPS theses by Oremis [2000] and Ardic [2001] describe integer linear programs to help the Army implement BRAC decisions.

What's an integer linear program?
Optimal Stationing of Army Forces (OSAF) includes an integer linear program that can be expressed in the following form:

$$\begin{array}{ll} \text{minimize} & \boldsymbol{cx} \\ \text{subject to} & \boldsymbol{Ax} = \boldsymbol{b}, \boldsymbol{x} \geq \boldsymbol{0}, \\ & x_j \in \{0,1\}\ \forall j \in R; \end{array}$$

where $\boldsymbol{c}$ and $\boldsymbol{x}$ are n-vectors, $\boldsymbol{b}$ is an m-vector, $\boldsymbol{A}$ is an $m \times n$ matrix, and R is an index set of binary variables. An instance of the program is specified by the data ($\boldsymbol{c}$, $\boldsymbol{b}$, and $\boldsymbol{A}$). For a typical OSAF instance, m is about 44,000, n is about 70,000, and R contains about 2,800 elements. It takes about five minutes to optimally solve a typical instance using commercially available optimization software. Connors, Dell and Tarantino [2002] provide additional detail.

2. OSAF INSTALLATIONS AND UNITS

The Army categorizes its installations by primary mission into 13 types, but OSAF addresses only the five types at which the preponderance of United States soldiers are stationed:

- maneuver,
- command and control,
- professional schools,
- major training areas, and
- training schools.

OSAF models each installation's available heavy and light maneuver training capacity, ranges, and other facilities, and unit requirements for these assets. For year 2009, we are stationing a force structure consisting of more than 3,500 major units at over 60 installations and training areas, as well as 11 major leased facilities. OSAF also models National Guard and Reserve Component requirements.

OSAF must account for the building types and ranges that are required by units stationed at an installation (unit requirements). The Army divides its building types and ranges into 353 facility category groups (FCGs), which are inventoried in the Army Real Property Planning and Analysis System. However, only a handful of these 353 FCGs provide the majority of the square footage that units require. For example, 25 FCGs comprise 80% of all square footage of buildings in the Army, while 50 FCGs comprise approximately 90%.

Most OSAF model instances consider 39 FCGs aggregated into the following nine groups:

- operations,
- administrative,
- aviation maintenance,
- vehicle maintenance,
- supply and storage,
- training instruction (active force),
- community facilities,
- unique facilities, and
- enlisted unaccompanied housing.

The Installation Status Report provides a quality rating (green for good, yellow for fair, and red for poor) for each square foot of each FCG at each installation. OSAF combines these groups into "green" and "other" and ensures that any unit moved to a new installation is given green-rated facilities or new construction. If only other-rated facilities are available for a moved unit, a cost to upgrade existing facilities to green-rated is applied in the model. OSAF does not upgrade facilities for units whose stationing does not change (units that do not move) and assumes that no green-rated facilities are evacuated by units leaving an installation unless all other-rated facilities are evacuated.

OSAF uses maneuver and range-day requirements from the Installation Training Capacity/Army Range Requirements Model (ITC/ARRM). Most OSAF model instances encompass the 18 range types given the most importance in the ITC. Range requirements are expressed in range-days and maneuver land requirements are expressed in kilometer^2-days. OSAF usually restricts the deviation between the required and available training assets, and in so doing it ensures that moving units do not increase training asset shortfalls. A subset of units can train at installations to which they are not assigned, proximity allowing.

3. OSAF COSTS

OSAF typically minimizes the 20-year Net Present Value (NPV) of stationing a given force structure. Consistent with prior stationing analyses, OSAF considers both recurring and one-time costs. Recurring costs are further divided into fixed and variable costs.

Fixed costs occur regardless of the number of soldiers on an installation and include certain operating costs for garrison activities (for example, fire protection, grounds maintenance) and minimum community facilities (for example, fitness centers, medical facilities). Cost factors and relationships are obtained from standard Army sources such as the Unit Relocation Cost Model and the Installation Status Report.

Every unit stationed on an installation generates a variable cost for installation operations, which OSAF implements as a cost per soldier or civilian assigned to the installation. OSAF uses variable costs based on these cost categories:

- base operating support,
- sustainment repair and modernization,
- medical,
- locality pay, and
- housing operations and allowances.

All stationing actions that include the movement of a unit or closure of an installation incur one-time costs in military construction (MILCON), transportation, and program management. If an installation that receives a new unit does not have the required green-rated facilities or ranges available, then a one-time MILCON cost is assessed for new construction or an upgrade from other-rated facilities, if such facilities are available.

All unit movements also incur a one-time transportation cost that includes the movement of civilians, equipment, military families, and the military unit.

4. EVALUATING A STATIONING PLAN

OSAF creates an optimal stationing plan while considering unit requirements, stationing restrictions and costs. But stationing a force structure is a complex problem that should be evaluated using many criteria, not all of which can be incorporated in the model. Hence, a post-optimization review of a proposed plan is normally carried out using these six metrics.

- **NPV and Investment** is the 20-year NPV of the stationing plan, as well as the one-time cost for transportation, MILCON, and program management.

- **Complexity** is measured by the number of units moved.

- **Joint Possibilities** reveal the impact on inter-Service stationing, as suggested by the Government Accounting Office (GAO) and others, stressing the importance of installation use by more than one Service in future stationing analyses. (We are currently investigating how to expand OSAF for use with the other Services.)

- **Utilization Factors** are reported for facilities, ranges, and lands where a low utilization rate could justify mothballing or demolition of facilities.

- **Impact Assessment** is more subjective and incorporates a review panel's guidance on issues that are difficult to capture in OSAF such as: strategic implications, quality

of life, environment, and ease of mobilization or deployment. Strategic implications represent, mainly from a geographical perspective, the Army's ability to fulfill its mission. For example, the Army cannot station all of its forces on one coastline (even if that appeared to be cost effective). We examine quality of life using standard Army metrics for an installation and its surrounding community. Environmental assessment includes remediation costs and involves analysis using standard Army models. For unit deployment and mobilization requirements, we determine if the stationing of a large maneuver force will stress existing deployment infrastructure (for example, railheads, airfields) and training infrastructure (for example, ranges) at the unit's new location.

- **Other.** Each installation has its own set of "special considerations." If these are added as constraints, OSAF can determine the cost of imposing them.

5. RESULTS

OSAF's prescribed plans have produced many insights, but we have also learned much in gathering and analyzing the input data and by building the model. Insights are gained more easily because all assumptions and constraints for each scenario are documented and stated explicitly, every optimized plan automatically satisfies the myriad details expressed in the underlying constraints, and every proposed solution is the best that can be achieved under the circumstances.

In 1997, GAO concluded that the "DOD continues to maintain large amounts of excess infrastructure, especially in its support functions, such as maintenance depots, research and development laboratories, and test and evaluation centers." We have found excess infrastructure in the OSAF-evaluated installation types, but not to the extent that GAO reports in support installations.

Our analysis shows it is possible to mitigate, to a degree, the imbalance of training land throughout the Army. When we examine today's overall Army, there is enough total training land, but with the current stationing, numerous installations cannot meet their unit requirements. By moving units, we can improve the balance between available land and unit requirements, but data indicate that just a few installations encompass the majority of training land. Thus, full utilization of this land would require extensive relocation and implementation costs, including MILCON. For example, installations in Alaska comprise over 50% of the Army's light maneuver land and over 30% of its total maneuver land, but it is not the ideal location for the preponderance of United States forces (even if we ignore strategic issues). Alaska is also one of the highest-cost areas and imposes strict environmental restrictions.

Army unit realignments and base closures have the potential to save the Army billions of dollars (NPV), but savings are not realized for many years because of initial implementation costs. Figure 1 represents eight different hypothetical stationing plans that each minimize NPV subject to a different implementation budget. Each point in the graph is a stationing alternative and represents the 20-year NPV (y-axis, $billions) at different implementation costs (x-axis, $billions). The origin is the status quo, with zero implementation cost and no savings. In the solutions presented in Figure 1, an investment of about $1.5 billion provides most of the possible 20-year NPV savings.

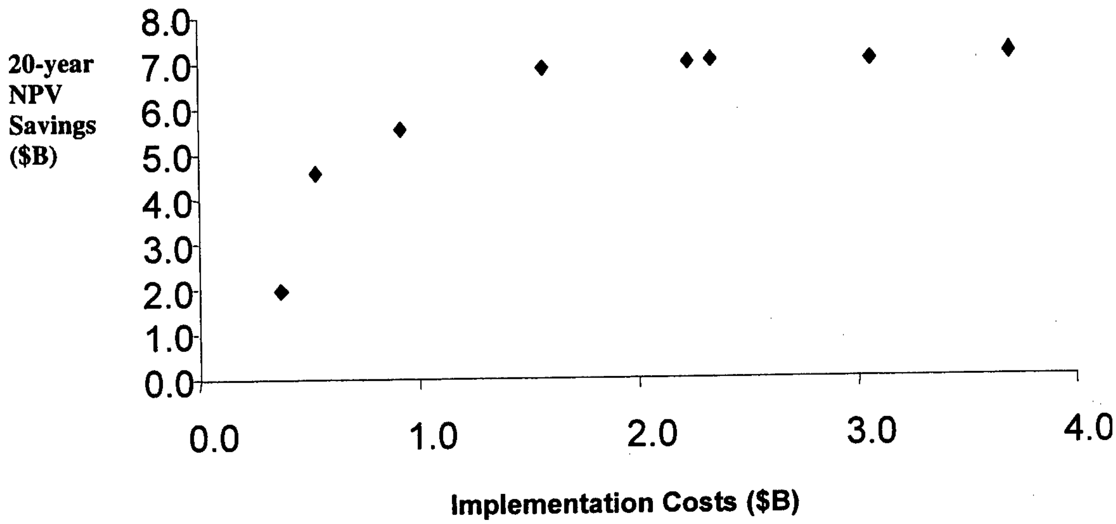

Figure 1. For these hypothetical stationing plans, an investment of $1.5 billion yields most of the maximum possible 20-year NPV savings.

6. UNCERTAIN DATA AND INTANGIBLES

Many man-years have been devoted to gathering and analyzing OSAF data. Despite the substantial effort, we are mindful of many limitations in this data and limitations imposed by other intangibles:

- **BRAC costs.** The costs forecasted for past BRAC actions have been hard to reconcile with subsequent actual costs [GAO 1997].
- **Economic assistance.** OSAF does not consider the cost of assistance to local communities to overcome realignment impacts. Although these costs may be substantial, they are also difficult to estimate in advance of any announced action [GAO 1996].
- **Environmental costs.** One of the largest costs DOD can face at an installation is for environmental remediation. GAO [1997] states that "we have concurred with DOD not considering these costs in developing its cost and savings estimates as a basis for base closure recommendations. At the same time, we agree with DOD's position that environmental restoration costs are a liability to it regardless of its base closure decisions; and we note, these costs are substantial."
- **Environmental issues other than cost.** Unfortunately, there are many environmental factors that can impact a stationing decision. For example, encroachment, due to growth in the installation's local community, can complicate new construction. Other installations may have long-term waivers or permits that could influence mission accomplishment. Such issues must be carefully investigated for any BRAC recommendation.

Armed with solutions to hundreds of OSAF scenarios, along with post-solution analyses and adjustments by experts, we can better understand and help mitigate the consequences of intangibles and uncertain cost estimates.

7. SUMMARY AND FUTURE USE

OSAF addresses a complex problem, a stationing analysis of the United States Army. OSAF quickly prescribes an optimal stationing plan for a given set of inputs and stationing restrictions.

We have continuously refined OSAF based on reviews by the Army leadership, our analyses to support the 2001 Quadrennial Defense Review, several case study analyses, and our studies to support the most recent Army stationing decisions.

Many in DOD have suggested that all Services would benefit from a joint analysis using OSAF. We agree that there is much to gain from a joint OSAF effort, but we hasten to warn that developing the data and details necessary to support such a large-scale decision in reasonable detail requires significant, continuing commitment and resources. The Army has made this commitment, and as a result of using optimization, enjoys additional benefits:

- All assumptions and constraints for each scenario are documented and stated explicitly. This means that each stake-holder can state a case on a level playing field, with transparency to all others.

- Every optimized plan satisfies the myriad details expressed in the underlying constraints. This means that valid comparisons between competing plans can be made quickly.

- Every proposed solution is the best that can be achieved under the circumstances. This is a comfort when dealing with contentious decisions involving huge amounts of our national treasure.

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